

# NetSim<sup>®</sup>

Accelerate Network R & D

## Software Defined Networks

A Network Simulation & Emulation Software

By



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# 1 About SDN

The salient features of SDN are:

- **Directly programmable:** SDN decouples the network control and forwarding functions. SDN allows programming the network control plane by abstracting the physical infrastructure.
- **Agile:** Decoupling and abstracting network control from forwarding helps administrators dynamically adjust network-wide traffic flow to meet the changing needs in the networks.
- **Centrally managed:** Network intelligence is centralized (logically) in software based SDN controllers that maintain a global view of the network, which appear to applications and policy engines as a single, logical switch.
- **Programmatically configured:** SDN lets network managers configure, manage, secure, and optimize network resources very quickly via dynamic, automated SDN programs, which they can write easily and quickly, because the programs do not depend on proprietary software.
- **Open standards-based and vendor-neutral:** Because SDN is implemented through open standards, SDN simplifies network design and operation because instructions are provided by SDN controllers instead of multiple, vendor-specific devices and protocols.

## 2 SDN in NetSim

SDN is available in NetSim from version 11 onwards. NetSim 'simulates' OpenFlow protocol. OpenFlow is an open interface to remotely control the forwarding tables in network switches, routers, etc.

### 2.1 SDN Controller in NetSim

An SDN controller is an application in SDN that manages flow control to enable intelligent networking. SDN controller can be used to control the packet forwarding of all Layer 3 devices in the network.

SDN controller lies between the network devices and the applications. Any communication between applications and devices must go through the controller.

NetSim has inbuilt controllers that 'simulate' SDN. An SDN controller in NetSim contains a Command Line Interface (CLI) to allow you to configure properties, such as, the IP forwarding table for different devices in the network.

NetSim also provides a platform whereby users can develop various kind of commands/interface compatible to any SDN enabled device.

In NetSim, any Layer 3 device can be configured as an SDN Controller. Multiple controllers can be configured in a network scenario. The following is a list of Layer 3 devices you can configure as an SDN controller:

- Internetworks – Nodes (Wired, Wireless Node), L3 Switches, Routers
- MANETs – Nodes (Wired, Wireless Node), Bridge Node (Wired, Wireless Node), Routers
- WSN - Sensors and Sink Node
- IOT - Sensors and Gateway (LowPAN Gateway), Nodes (Wired, Wireless Node), Routers
- Cognitive Radio – CR CPE, Nodes (Wired, Wireless Node), Routers
- LTE – UE, EPC, Nodes (Wired, Wireless Node), Routers
- VANETs – Vehicle and RSU
- 5G mmWave – UE, EPC, Nodes (Wired, Wireless Node), Routers

**Note:** NetSim 'simulates' SDN protocol and cannot connect to real controllers such as Open Daylight.

### 2.2 CLI Commands for SDN in NetSim

You can use the following commands when you simulate SDN in NetSim:

**Simulation-specific** – Pause, PauseAt, Continue, Stop, Exit, and Reconnect.

**Route** – route add, route print, and route delete.

**Ping Command** – ping (not supported on some network types, for example, Wireless Sensor Network)

**ACL configuration** – ACL Enable, ACL Disable, ACL Print, and aclconfig.

**Note:** CLI commands in NetSim are NOT case-sensitive. To get detailed help about how to use CLI commands in NetSim, **Section 3.5** NetSim Interactive Simulation in User Manual.

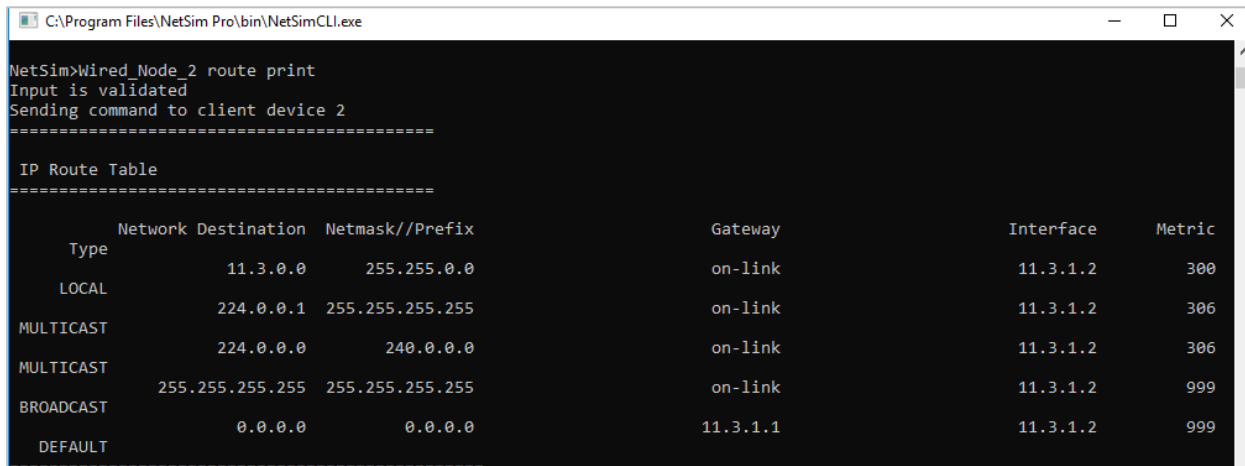
## 2.3 How to use CLI Commands for SDN

Each device in NetSim has a console which can be accessed by right clicking on the device. Users can execute supported SDN commands on the console of the SDN controller node to configure other nodes in the network. Let us look at a few examples.

**Example 1:** To view the IP routing table of a node that is controlled by the SDN controller, use the following command syntax: **<DeviceName with Device\_ID> route print**.

For example, type **Wired\_Node\_2 route print** and press **Enter**.

The following image illustrates the output for the command.



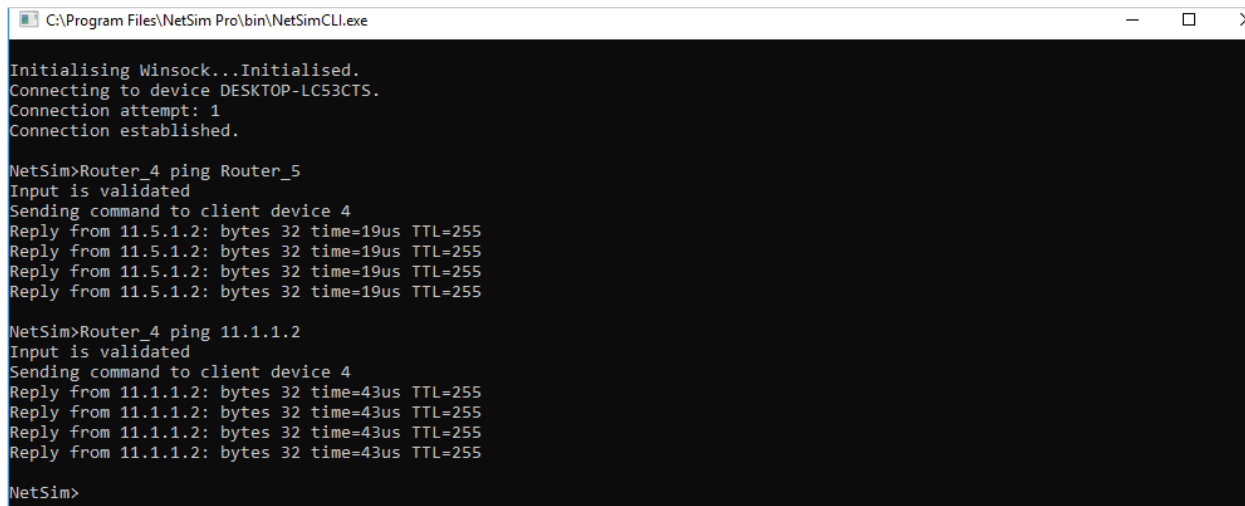
```
NetSim>Wired_Node_2 route print
Input is validated
Sending command to client device 2
=====
IP Route Table
=====
Type      Network Destination  Netmask/Prefix      Gateway      Interface      Metric
-----
LOCAL     11.3.0.0              255.255.0.0         on-link      11.3.1.2        300
MULTICAST 224.0.0.1            255.255.255.255     on-link      11.3.1.2        306
MULTICAST 224.0.0.0             240.0.0.0           on-link      11.3.1.2        306
BROADCAST 255.255.255.255       255.255.255.255     on-link      11.3.1.2        999
DEFAULT   0.0.0.0               0.0.0.0             11.3.1.1     11.3.1.2        999
=====
```

Figure 2-1: Printing IP routing table in Console

**Example 2:** To initiate ping from one node to another node where both nodes are controlled by the SDN controller, following command can be executed in the SDN controller:

**<DeviceName with Device\_ID> Ping <DeviceName with Device\_ID> or <DeviceName with Device\_ID> Ping <IP Address>.**

For example, type **Router\_4 ping Router\_5** or **Router\_4 ping 11.1.1.2** and press **Enter**.

A screenshot of a Windows command prompt window titled "C:\Program Files\NetSim Pro\bin\NetSimCLI.exe". The window has a black background with white text. The text shows the initialization of Winsock, connection to device DESKTOP-LC53CTS, and two successful ping operations. The first ping is from Router\_4 to Router\_5 (11.5.1.2) with three replies showing 32 bytes, 19us time, and TTL=255. The second ping is from Router\_4 to 11.1.1.2 with three replies showing 32 bytes, 43us time, and TTL=255. The prompt "NetSim>" is visible at the bottom.

```
C:\Program Files\NetSim Pro\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-LC53CTS.
Connection attempt: 1
Connection established.

NetSim>Router_4 ping Router_5
Input is validated
Sending command to client device 4
Reply from 11.5.1.2: bytes 32 time=19us TTL=255
Reply from 11.5.1.2: bytes 32 time=19us TTL=255
Reply from 11.5.1.2: bytes 32 time=19us TTL=255
Reply from 11.5.1.2: bytes 32 time=19us TTL=255

NetSim>Router_4 ping 11.1.1.2
Input is validated
Sending command to client device 4
Reply from 11.1.1.2: bytes 32 time=43us TTL=255
Reply from 11.1.1.2: bytes 32 time=43us TTL=255
Reply from 11.1.1.2: bytes 32 time=43us TTL=255
Reply from 11.1.1.2: bytes 32 time=43us TTL=255

NetSim>
```

Figure 2-2: Pinging Router\_4

**Note:** In order to initiate ping between the devices, ICMP protocol which is present in the Network Layer properties of the devices must be set to TRUE.

## 2.4 Excluded Features

Multiple controllers can be configured in NetSim. However, intercontroller communication requires the user to write their own code in NetSim.

## 3 Featured Examples

NetSim provides inbuilt examples to get started with the SDN module. To access these examples, you can go to **Examples > Software-Defined-Networks** in the NetSim Home Screen. You can change the default values of the parameters in these examples and see how they affect the performance of the SDN network.

### 3.1 Example 1: Configuring One SDN Controller in a Simple Internetwork

The Internetwork model in this example consists of the following configuration:

1. A subnet with 2 wired nodes, 3 routers, and a unicast application running on one of the wired nodes.
2. Only one router is configured as the SDN controller.
3. Open Flow protocol is enabled on all wired nodes and routers.
4. A unicast application is set between `Wired_Node_1` to `Wired_Node_2`.
5. Set Transport Protocol to TCP in Application icon present in the top ribbon/toolbar.
6. Simulation time is set to 500 seconds.
7. Plots, Packet trace, and Event trace logs are enabled.

To simulate the example for One SDN controller in an Internetwork:

Open NetSim and Select **Examples > Software Defined Networks > Configuring SDN > SDN Internetworks** then click on the tile in the middle panel to load the example as shown in below

**NetSim Standard**  
Network Simulation/Emulation Platform  
Version 13.1.19 (64 Bit)

**Example Simulations**

- > Internetworks
- > Cellular Networks
- > Advanced Routing
- > Mobile Adhoc Networks
- > Software Defined Networks
  - Configuring SDN
    - SDN Internetworks**
    - WSN Setting Multiple SDN Controllers
    - MANET StaticRoute
    - Internetworks StaticRoute
    - WSN StaticRoute
  - > IOT-WSN
  - > Cognitive Radio Networks
  - > LTE and LTE-A
  - > VANETs
  - > Satellite Communication
  - > 5G NR

**SDN Internetworks**

A simple example with involving one SDN controller. This example is developed in the internetworks library.

Enabled open flow in all devices  
Changed SDN controller device name  
Transport protocol: TCP

**Results**

Network diagram showing Router\_3, Router\_5, SDN\_Controller, Wired\_Node\_1, and Wired\_Node\_2 connected. A unicast application (App1\_CBR) is running between Wired\_Node\_1 and Wired\_Node\_2.

Device Name	Open_Flow	SDN_Controller	SDN_Controller_DeviceName
Wired_Node_1	Enable	FALSE	SDN_Controller
Router_3	Enable	FALSE	SDN_Controller
SDN_Controller	Enable	TRUE	NA
Router_5	Enable	FALSE	SDN_Controller
Wired_Node_2	Enable	FALSE	SDN_Controller

Ready to simulate scenarios to understand the working of the different technology libraries in NetSim. Expand and click on the file name to display simulation examples. Then click on a tile in the middle panel to load the simulation. Click on the book icon on the left (Example Simulations) panel to view documentation (pdf).

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Figure 3-1: List of scenarios for the example of SDN Internetworks



The following network diagram illustrates what the NetSim UI displays when you open the example configuration file for SDN as shown Figure 3-2.

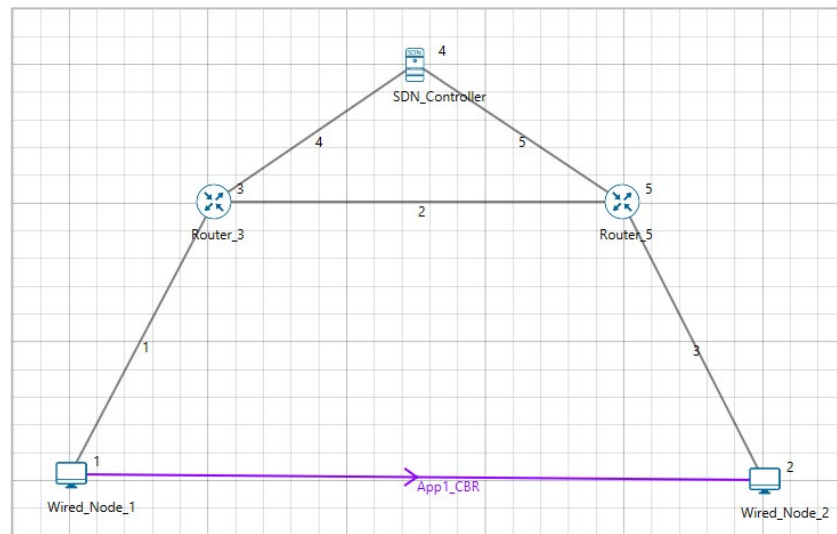


Figure 3-2: Network set up for studying the SDN Internetworks

1. In the application layer of the SDN Controller node:

- a. **SDN\_Controller** option set to **TRUE**.
- b. **Open\_Flow** protocol is enabled.

The following image illustrates the settings done in the SDN controller device:

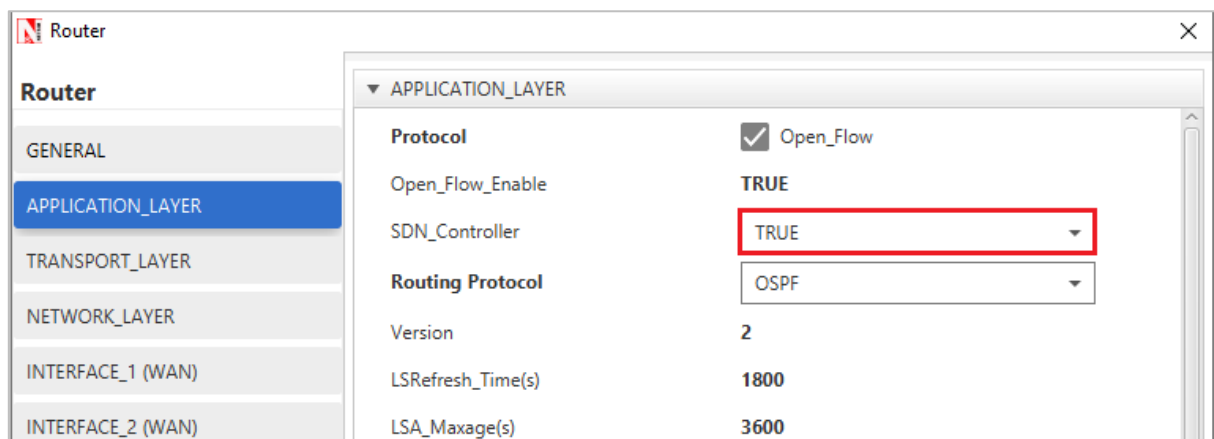


Figure 3-3: Application Layer properties Window of SDN\_Controller

2. In the other devices (Routers and wired node) that are part of the network,

- a. **SDN\_Controller** option is set to **FALSE**.
- b. **SDN\_Controller\_DeviceName** is set as “**SDN\_Controller**” which is the name of the controller node.
- c. **Open\_Flow** protocol is enabled.

The following image illustrates settings done in the other devices:

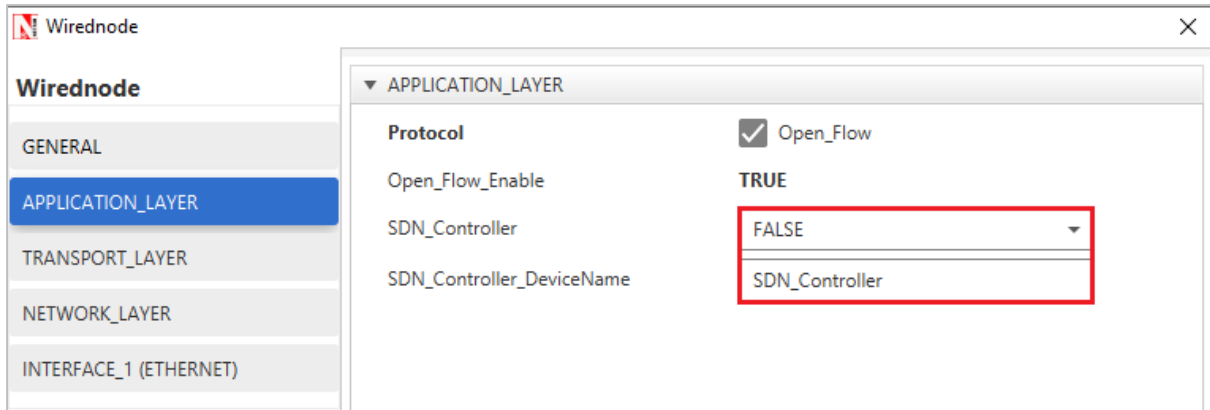


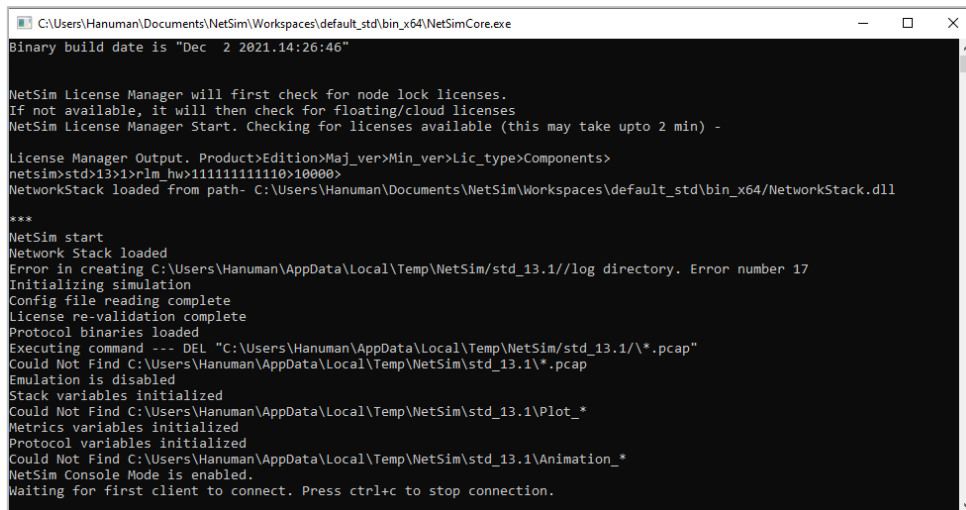
Figure 3-4: SDN\_Controller\_DeviceName is set as SDN\_Controller in Application layer  
The following table lists the settings done in all the devices that are part of the network:

Device Name	Open_Flow	SDN_Controller	SDN_Controller_DeviceName
Wired_Node_1	Enable	FALSE	SDN_Controller
Router_3	Enable	FALSE	SDN_Controller
SDN_Controller	Enable	TRUE	NA
Router_5	Enable	FALSE	SDN_Controller
Wired_Node_2	Enable	FALSE	SDN_Controller

**Table 3-1:** Set the properties for all the devices

3. Click on the Application icon present in the top ribbon/toolbar.
  - a. CBR Application from Wired Node 1 to Wired Node 2 with 50 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 233.6μs).
  - b. Set Transport Protocol to TCP.
4. Simulate the example. To do so:
  - a. Click on the Run. The Run Simulation pop-up window appears.
  - b. Simulation time is set to 500 Seconds.
  - c. In the Run time Interaction tab, Interactive Simulation option is set to True.
  - d. Click **Accept**.
  - e. Click **OK**.

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for first client to connect.



```
C:\Users\Hanuman\Documents\NetSim\Workspaces\default_std\bin_x64\NetSimCore.exe
Binary build date is "Dec  2 2021.14:26:46"

NetSim License Manager will first check for node lock licenses.
If not available, it will then check for floating/cloud licenses
NetSim License Manager Start. Checking for licenses available (this may take upto 2 min) -

License Manager Output. Product>Edition>Maj_ver>Min_ver>Lic_type>Components>
netsim>std>13>1>rlm_hw>11111111110>10000>
NetworkStack loaded from path- C:\Users\Hanuman\Documents\NetSim\Workspaces\default_std\bin_x64\NetworkStack.dll

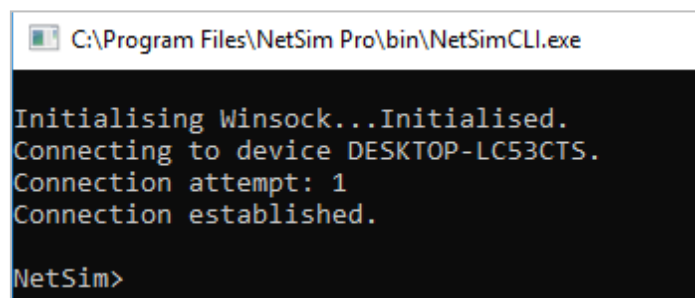
***
NetSim start
Network Stack loaded
Error in creating C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\log directory. Error number 17
Initializing simulation
Config file reading complete
License re-validation complete
Protocol binaries loaded
Executing command --- DEL "C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\*.pcap"
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\*.pcap
Emulation is disabled
Stack variables initialized
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\Plot_*
Metrics variables initialized
Protocol variables initialized
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\Animation_*
NetSim Console Mode is enabled.
Waiting for first client to connect. Press ctrl+c to stop connection.
```

Figure 3-5: Waiting for first client to connect

5. To use the SDN CLI Console:

- a. Right-click **SDN\_Controller** and select NetSim Console. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.

The following image illustrates the NetSim CLI console.



```
C:\Program Files\NetSim Pro\bin\NetSimCLI.exe

Initialising Winsock...Initialised.
Connecting to device DESKTOP-LC53CTS.
Connection attempt: 1
Connection established.

NetSim>
```

Figure 3-6: Connection established

- b. Use this console to execute SDN commands.

## 3.2 Example 2: Configuring Multiple SDN Controllers in a Wireless Sensor Network

In this example, multiple SDN controllers are configured in a Wireless Sensor Network.

The Wireless Sensor Network model in this example consists of the following configuration:

- A subnet with 4 wireless sensors, 1 ad-hoc link, 1 WSN sink node, and a unicast sensor application running on one of the wireless sensors.
- Set Transport Protocol to TCP in Application icon present in the top ribbon/toolbar.
- Two wireless sensors are configured as SDN controllers.
- Open Flow protocol is enabled on all wireless sensors and sink node.

NetSim uses the following defaults for this SDN example:

- a. The unicast application transmits data from Wireless Sensor\_3 to Wireless Sensor\_5.
- b. Simulation runs for 500 seconds.
- c. Plots, Packet trace, and Event trace is enabled.

**Note:** For a WSN network, ping command is not supported on ZigBee device since these nodes do not support ICMP protocol.

To simulate the example for multiple SDN controllers in WSN for SDN:

Open NetSim and Select **Examples > Software Defined Networks > Configuring SDN > WSN Setting Multiple SDN Controllers** then click on the tile in the middle panel to load the example as shown in below screenshot

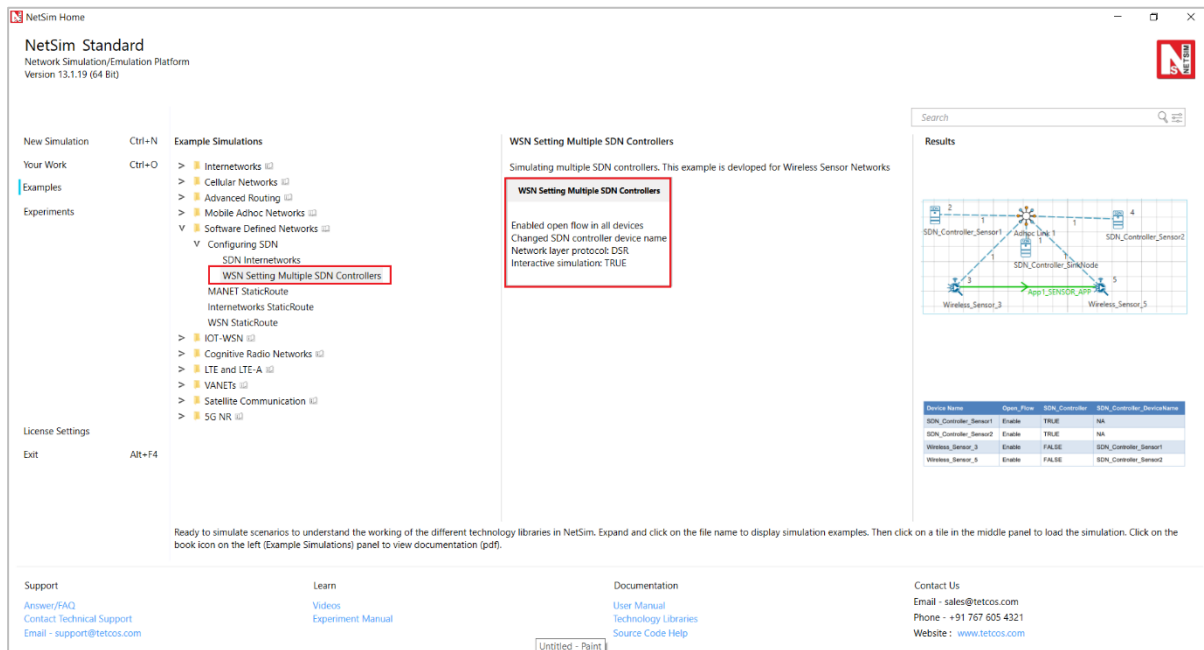


Figure 3-7: List of scenarios for the example of WSN Setting Multiple SDN Controllers

The following network diagram illustrates the network setup related to this example as shown below Figure 3-8.

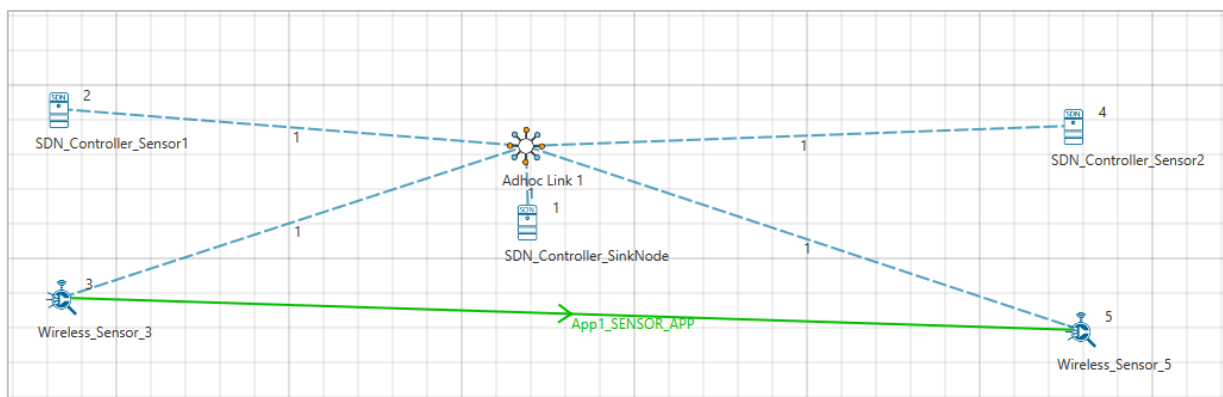


Figure 3-8: Network set up for studying the WSN Setting Multiple SDN Controllers

1. The sensors 1, 2 and the sinknode are configured as SDN controllers with Open Flow protocol enabled in all the nodes.

The following image illustrates the settings done in the sensors configured as SDN controller as shown below Figure 3-9.

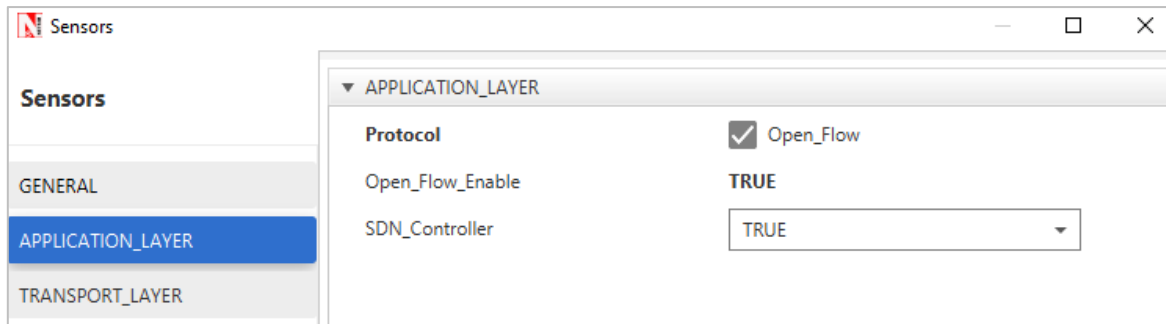


Figure 3-9: Application Layer properties Window

2. The sensor SDN\_Controller\_Sensor\_1 is set as the SDN controller for Wireless\_Sensor\_3 and SDN\_Controller\_Sensor\_2 is set as the SDN controller for Wireless\_Sensor\_5.

The following image illustrates the settings done in sensor 3 as shown Figure 3-10.

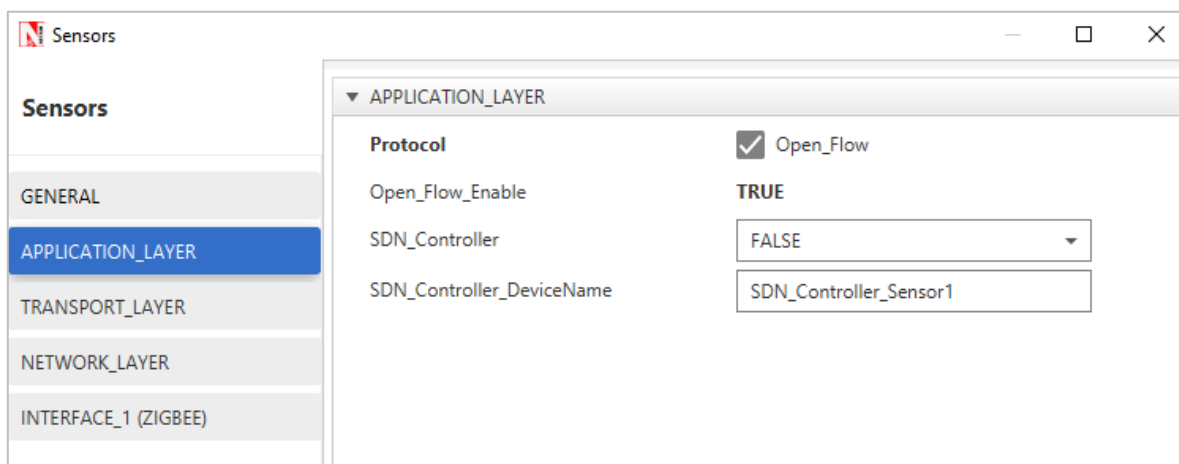


Figure 3-10: SDN\_Controller\_DeviceName is set as SDN\_Controller in Application layer

The following table lists the default setting for the wireless sensors.

Device Name	Open_Flow	SDN_Controller	SDN_Controller_DeviceName
SDN_Controller_Sensor1	Enable	TRUE	NA
SDN_Controller_Sensor2	Enable	TRUE	NA
Wireless_Sensor_3	Enable	FALSE	SDN_Controller_Sensor1
Wireless_Sensor_5	Enable	FALSE	SDN_Controller_Sensor2

Table 3-2: Set the properties for all the devices

3. Click on the Application icon present in the top ribbon/toolbar.
  - a. Sensor Application from Wireless\_Sensor\_3 to Wireless\_Sensor\_5 with Packet Size: 50Bytes, Inter Arrival Time: 1000000μs).
  - b. Set Transport Protocol to TCP.
4. Additional analysis options such as plots, packet trace and event trace are enabled.
5. Simulate the example. To do so:
  - a. Click the Run button. The Run Simulation pop-up window appears.

- b. Simulation time is set to 500 seconds.
- c. In the Run time Interaction tab, Interactive Simulation option is set to True.
- d. Click **Accept**.
- e. Click **OK**.

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for first client to connect.

```

C:\Users\Hanuman\Documents\NetSim\Workspaces\default_std\bin_x64\NetSimCore.exe
Binary build date is "Dec  2 2021.14:26:46"

NetSim License Manager will first check for node lock licenses.
If not available, it will then check for floating/cloud licenses
NetSim License Manager Start. Checking for licenses available (this may take upto 2 min) -

License Manager Output. Product>Edition>Maj_ver>Min_ver>Lic_type>Components>
netsim>std>13>1>rlm_hw>111111111110>10000>
NetworkStack loaded from path- C:\Users\Hanuman\Documents\NetSim\Workspaces\default_std\bin_x64\NetworkStack.dll

***
NetSim start
Network Stack loaded
Error in creating C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\log directory. Error number 17
Initializing simulation
Config file reading complete
License re-validation complete
Protocol binaries loaded
Executing command --- DEL "C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\*.pcap"
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\*.pcap
Emulation is disabled
Stack variables initialized
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\Plot_*
Metrics variables initialized
Protocol variables initialized
Could Not Find C:\Users\Hanuman\AppData\Local\Temp\NetSim\std_13.1\Animation_*
NetSim Console Mode is enabled.
Waiting for first client to connect. Press ctrl+c to stop connection.
  
```

Figure 3-11: Waiting for first client to connect

#### 6. To use the SDN CLI Console:

- a. Right-click **SDN\_Controller\_Sensor1** or **SDN\_Controller\_Sensor2** and click NetSim Console.

Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe. The following image illustrates the NetSim CLI console.

```

C:\Program Files\NetSim Pro\bin\NetSimCLI.exe

Initialising Winsock...Initialised.
Connecting to device DESKTOP-LC53CTS.
Connection attempt: 1
Connection established.

NetSim>
  
```

Figure 3-12: Connection established

You can execute various SDN commands that are supported.

### 3.3 Example 3: How to Change the IP tables in devices in NetSim using SDN Commands

In the example the IP tables in the nodes and routers on an SDN network are modified using SDN CLI commands.

The network model in this example consists of the following configuration:

- A subnet with 2 wired nodes, 5 routers, and a unicast application running on one of the wired nodes.
- SDN controller running on one of the router.
- Set Transport Protocol to TCP in Application icon present in the top ribbon/toolbar. Open Flow protocol is enabled on all wired nodes and routers.
- A unicast application set from Wired\_Node\_1 to Wired\_Node\_2.
- OSPF is the routing protocol in the routers.
- The node SDN\_Controller is configured to be the SDN controller.
- Simulation time is set to 500 seconds.
- Plots, Packet trace, and Event trace is enabled.

To simulate SDN and change the IP tables:

Open NetSim and Select **Examples > Software Defined Networks > Internetworks StaticRoute** then click on the tile in the middle panel to load the example as shown in below screenshot

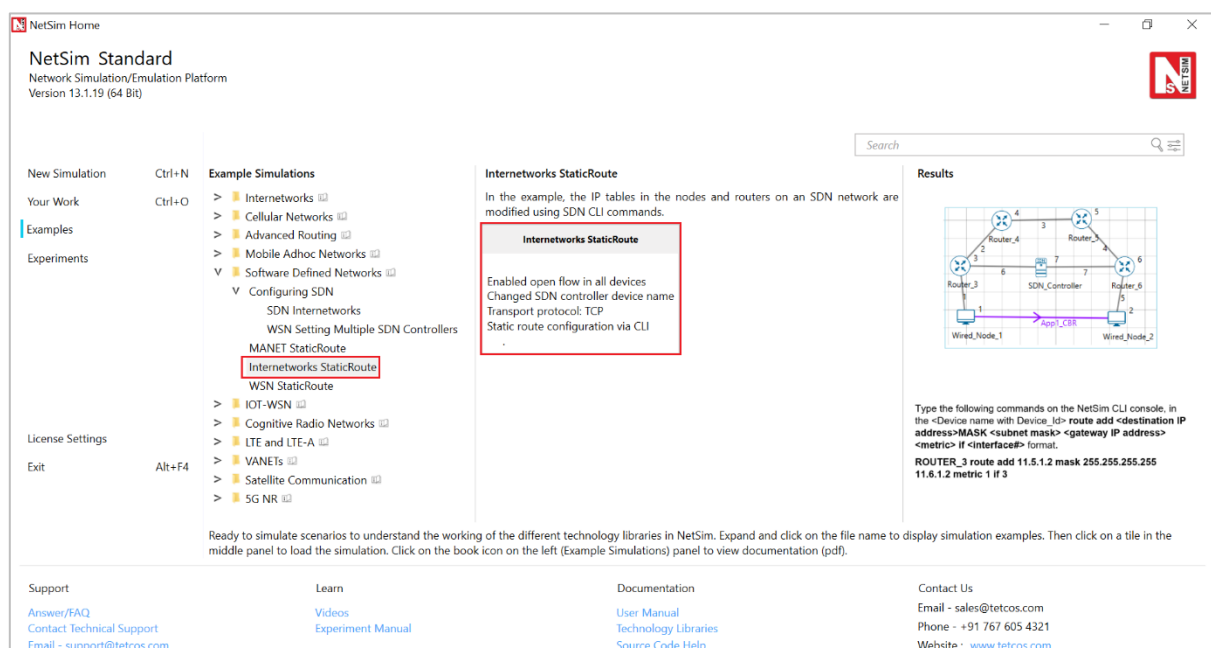


Figure 3-13: List of scenarios for the example of Internetworks StaticRoute

The following network diagram illustrates the network setup related to this example as shown below Figure 3-14.

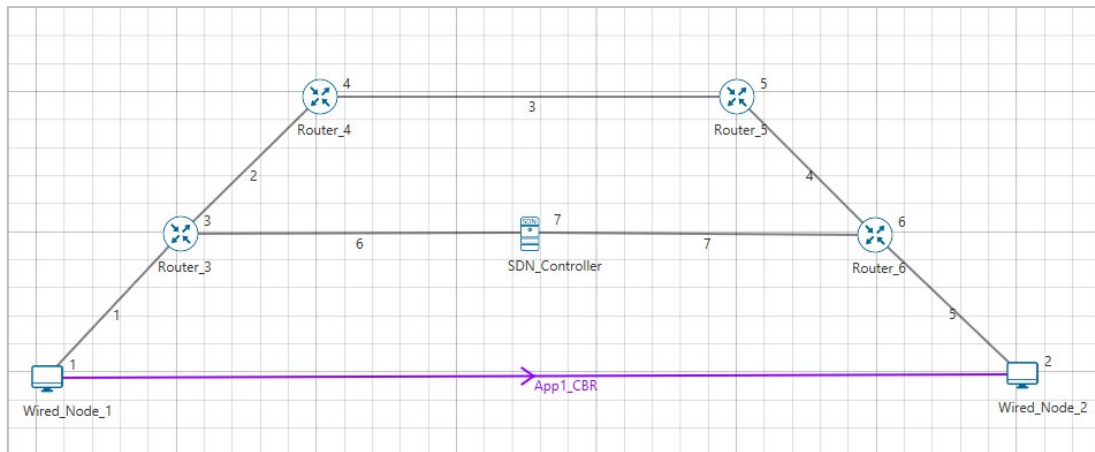


Figure 3-14: Network set up for studying the Internetworks StaticRoute

1. Click on the Application icon present in the top ribbon/toolbar.
  - a. CBR Application from Wired Node 1 to Wired Node 2 with 50 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 233.6μs).
  - b. Application Start time is 30 sec.
  - c. Set Transport Protocol to TCP.
2. Plots, Packet Trace and Event Trace features are enabled.
3. Simulate SDN. To do so:
  - a. Click the Run button. The Run Simulation pop-up window appears.
  - b. Simulation time is set to 500 Seconds.
  - c. In the Run time Interaction tab, Interactive Simulation option is set to True.
4. Right-click **SDN\_Controller** and click NetSim Console. NetSim simulates SDN.
5. Interpret the results.
  - a. Click View Animation and see the Packet Animation.

The packets reach Wired\_Node\_2 via Wired\_Node\_1 > Router 3 > SDN\_Controller > Router 6 as shown in Figure 3-15.



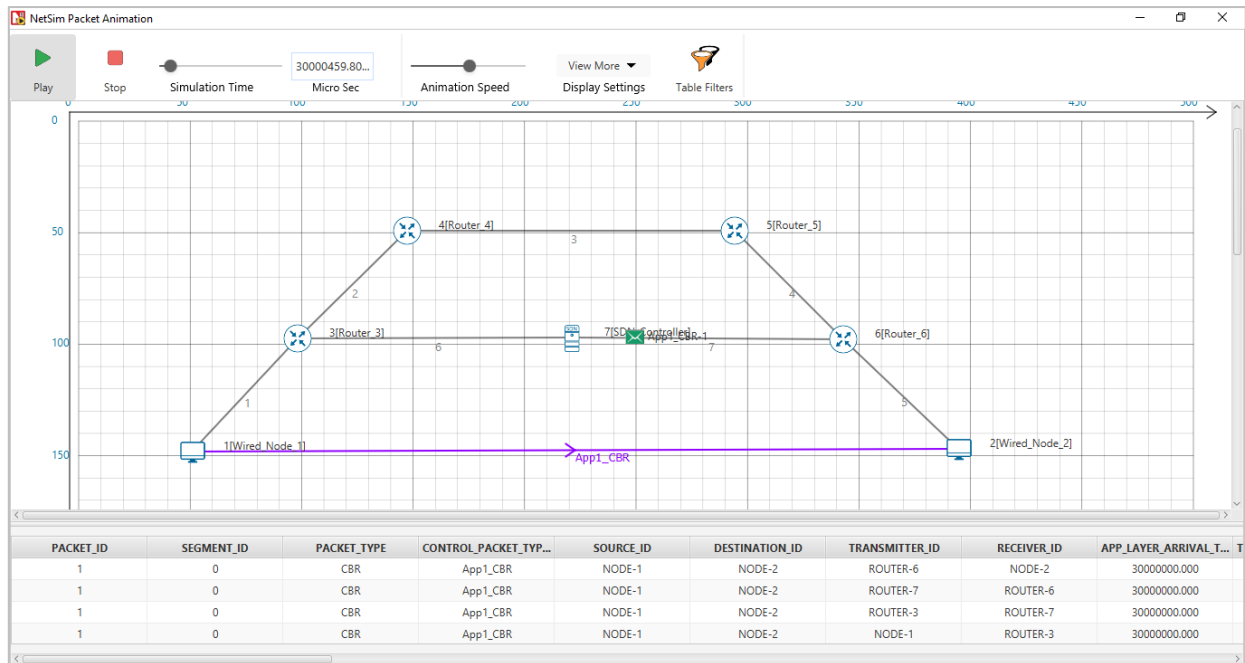


Figure 3-15: Packet Animation window

- b. Click **View Results** on the tool bar, **Link metrics** in the left area and check the **Detailed View** check box in the **Link\_Metrics\_Table** pop-up window.

You will not see data packet transmissions in Links 2, 3, and 4 as shown in below Figure 3-16.

Link_Metrics_Table									
Link_Metrics									
Link_id	Link_throughput_plot	Packet_transmitt...		Packet_errorred		Packet_collided		Bytes_transmitted(bytes)	Payload_transmitted(bytes)
		Data	Control	Data	Control	Data	Control		
All	NA	1888	4373	3	1	0	0	3174526	2752100
1	Link_throughput	473	473	0	0	0	0	753024	690580
2	Link_throughput	0	495	0	0	0	0	43348	0
3	Link_throughput	0	496	0	0	0	0	43524	0
4	Link_throughput	0	495	0	1	0	0	43448	0
5	Link_throughput	470	473	0	0	0	0	748446	686200
6	Link_throughput	473	970	1	0	0	0	772000	689120
7	Link_throughput	472	971	2	0	0	0	770736	686200

Figure 3-16: Link Metrics Table in result window

6. Configure static routes on Router\_3 such that all traffic bound for the 11.4.1.2 subnet will go to a gateway 11.2.1.2, that is, from Router\_3 > Router\_4 > Router\_5 > Router\_6.

#### To configure the static routes for Router\_3:

- Simulate the network again.
- Now, right-click **SDN\_Controller** and click NetSim Console.

Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.

NetSim CLI console opens.

- c. Type the following commands on the NetSim CLI console, in the *<DeviceName with Device\_ID>* **route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #>** format.

**ROUTER\_3 route add 11.5.1.2 mask 255.255.255.255 11.2.1.2 metric 1 if 2**

- d. (Optional) To check the static routes on ROUTER\_3, type **ROUTER\_3 route print**. The following image illustrates step (c) and (d) as shown below **Figure 3-17**.

```

C:\Program Files\NetSim Standard\bin\NetSimCLI.exe
Initialising Winsock...Initialised.
Connecting to device DESKTOP-1TG2NRI.
Connection attempt: 1
Connection established.

NetSim>ROUTER_3 route add 11.5.1.2 mask 255.255.255.255 11.2.1.2 metric 1 if 2
Input is validated
Sending command to client device 3
OK!

NetSim>ROUTER_3 route print
Input is validated
Sending command to client device 3
=====
IP Route Table
=====

```

ic	Network Type	Destination	Netmask//Prefix	Gateway	Interface	Metri
1	STATIC	11.5.1.2	255.255.255.255	11.2.1.2	11.2.1.1	
00	OSPF	11.6.1.2	255.255.0.0	11.6.1.2	11.6.1.1	2
00	OSPF	11.7.1.1	255.255.0.0	11.6.1.2	11.6.1.1	2
00	OSPF	11.2.1.2	255.255.0.0	11.2.1.2	11.2.1.1	2
00	OSPF	11.3.1.1	255.255.0.0	11.2.1.2	11.2.1.1	2

Figure 3-17: Route added to network and route printed in command

## 7. Interpret the results.

- Click **View Animation** and see the Packet Animation.
- The packets reach Wired\_Node\_2 via Router 3 > Router\_4 > Router\_5 > Router 6.
- Click **View Results** on the tool bar, **Link metrics** in the left area and check the **Detailed View** check box in the **Link\_Metrics\_Table** pop-up window.

You will see data packet transmissions in Links 2, 3, and 4.

The following figure illustrates step (7c) as shown in below.

Link_Metrics_Table										
Link_Metrics										
Link_id	Link_throughput_plot	Packet_transmitt...		Packet_errored		Packet_collided		Bytes_transmitted(bytes)	Payload_transmitted(bytes)	Overhead_transmitted(bytes)
		Data	Control	Data	Control	Data	Control			
All	<a href="#">NA</a>	2365	4382	4	1	0	0	3890591	3447075	443516
1	<a href="#">Link throughput</a>	474	473	0	0	0	0	754550	692040	62510
2	<a href="#">Link throughput</a>	474	497	1	0	0	0	754432	690580	63852
3	<a href="#">Link throughput</a>	473	498	1	0	0	0	753108	689120	63988
4	<a href="#">Link throughput</a>	472	497	0	1	0	0	751532	689120	62412
5	<a href="#">Link throughput</a>	472	473	2	0	0	0	751498	686200	65298
6	<a href="#">Link throughput</a>	0	975	0	0	0	0	62819	15	62804
7	<a href="#">Link throughput</a>	0	969	0	0	0	0	62652	0	62652

Figure 3-18: Link Metrics Table

- In the simulation results window click on the Open **Packet trace** option in the left area. Once the packet trace opens, apply display filters to the

**CONTROL\_PACKET\_TYPE/APP\_NAME** column to show only **OPENFLOW\_COMMAND** and **OPENFLOW\_RESPONSE** packets.

You will see that OpenFlow packets flow between Router\_3 to SDN\_Controller.

8. In Router\_3 under application layer use routing protocol as RIP

9. Configure static routes for Router\_3 as follows:

a. Simulate SDN (**Refer step 4**).

b. Right-click SDN\_Controller and click NetSim Console.

Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe. NetSim CLI console opens.

c. Type the following commands on the NetSim CLI console, in the *<DeviceName with Device\_ID>* **route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #>** format.

**ROUTER\_3 route add 11.5.1.2 mask 255.255.255.255 11.6.1.2 metric 1 if 3**

10. Interpret the results.

a. Click **View Animation** and see the Packet Animation. The packets reach Wired\_Node\_2 via Router 3 > SDN\_Controller > Router\_6.

### 3.4 Example 4: Configuring Static Routes for a MANET Network by using SDN

In this example static routes are configured using the SDN controllers, in a MANET network.

The MANET network model in this example consists of the following configuration:

- A subnet with 5 wireless nodes and 1 ad-hoc link, and a unicast CBR application running on one of the wireless nodes.
- DSR is the routing protocol that is enabled on all wireless nodes.
- One wireless node is configured as the SDN controller.
- Wireless nodes do not have mobility.
- A unicast application is configured from Wireless\_Node\_1 to Wireless\_Node\_5.
- Simulation time is set to 1000 seconds.
- Packet trace, and Event trace is enabled.

To simulate the example for MANET using SDN:

Open NetSim and Select **Examples > Software Defined Networks > MANET StaticRoute** then click on the tile in the middle panel to load the example as shown in below screenshot

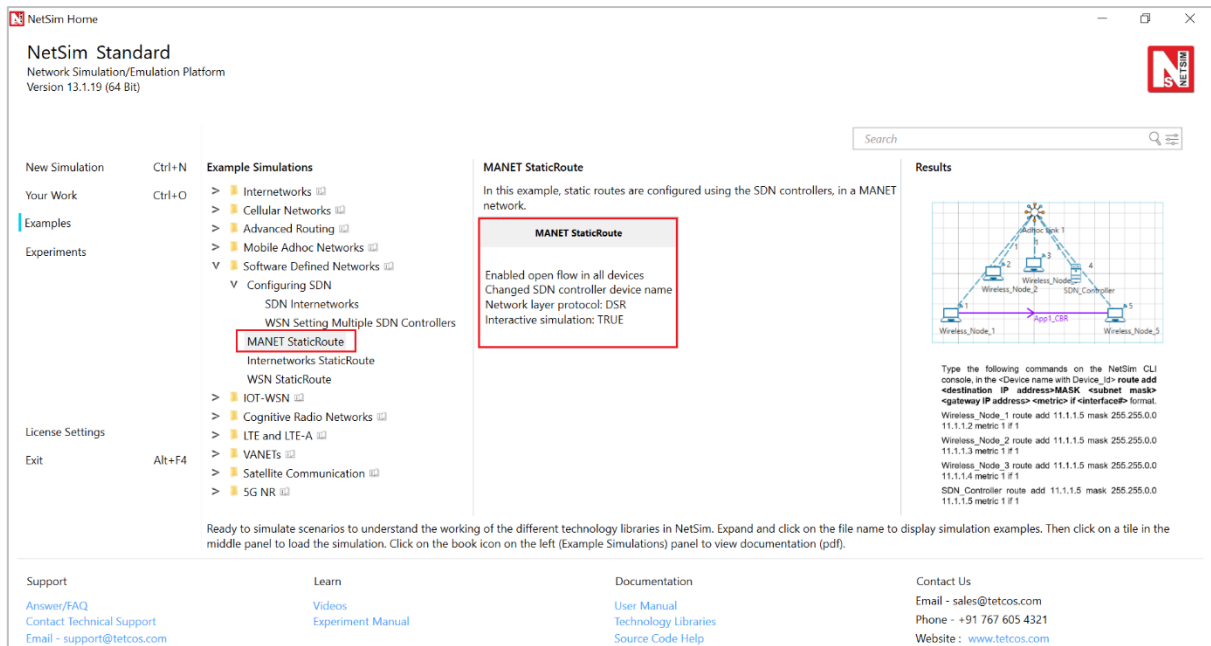


Figure 3-19: List of scenarios for the example of MANET StaticRoute

The following network diagram illustrates the network setup as shown Figure 3-20.

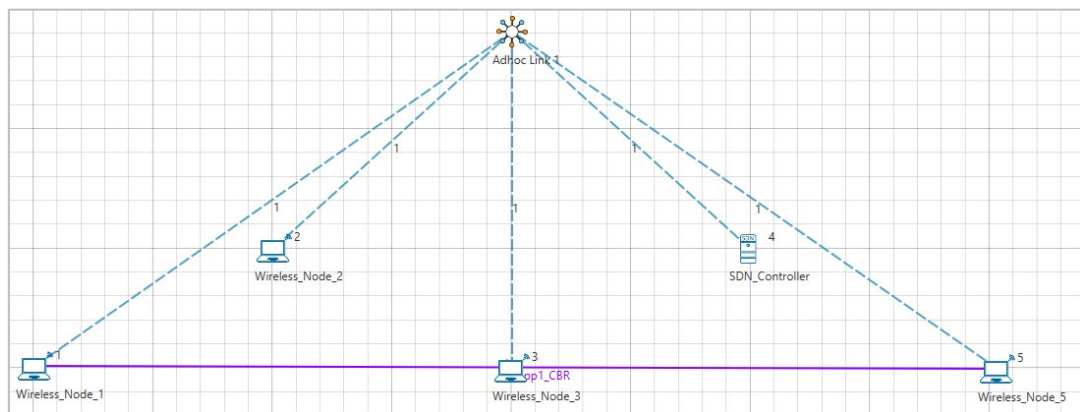


Figure 3-20: Network set up for studying the MANET StaticRoute

1. DSR routing protocol is configured in Network layer for all the nodes and set the nodes to be stationary.
2. Mobility model is set to NO\_MOBILITY in all the nodes.
3. ICMP protocol is enabled in the network layer properties of all the wireless nodes.
4. Open flow protocol is enabled in all the nodes.

The following settings were done in the wireless nodes to configure Wireless Node 4 as SDN controller and other nodes as its clients.

Device Name	Open_Flow	SDN_Controller	SDN_Controller_DeviceName
Wireless_Node_1	Enable	FALSE	SDN_Controller
Wireless_Node_2	Enable	FALSE	SDN_Controller
Wireless_Node_3	Enable	FALSE	SDN_Controller
SDN_Controller	Enable	TRUE	FALSE

Wireless_Node_5	Enable	FALSE	SDN_Controller
-----------------	--------	-------	----------------

Table 3-3: Set the properties for all the devices

5. Click on the Application icon present in the top ribbon/toolbar.
  - a. CBR Application from Wireless\_Node\_1 to Wireless\_Node\_5 with 0.584 Mbps Generation Rate (Packet Size: 1460Bytes, Inter Arrival Time: 20000μs).
  - b. Set Transport Protocol to UDP.
6. Channel Characteristics: Path Loss Only, Path Loss Model: Log Distance, Path Loss Exponent:3.2.
7. In NetSim GUI Plots, Packet Trace and Event Trace are enabled.
8. Simulate the example. To do so:
  - a. Click the Run button. The Run Simulation pop-up window appears.
  - b. Simulation time is set to 1000 seconds.
  - c. In the Run time Interaction tab, the Interactive Simulation option is set to True.
  - d. Click **Accept**.
  - e. Click **OK**.

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message:  
waiting for first client to connect.
9. To use the SDN CLI Console:
  - a. Right-click **SDN\_Controller** and select NetSim Console. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.
10. Interpret the results.
  - a. Click View Animation and see the Packet Animation.  
The packets reach Wireless\_Node\_5 from Wireless\_Node\_1-> SDN\_Controller -> Wireless\_Node\_5.

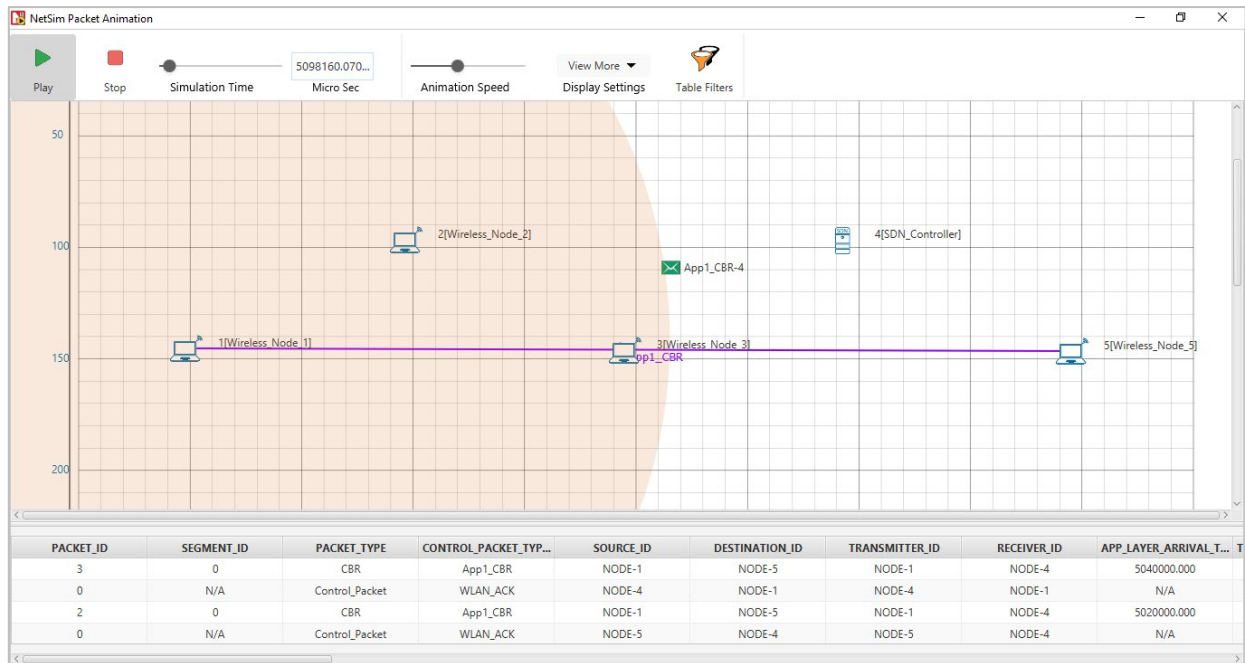


Figure 3-21 : Packet Animation window

11. Configure static routes such that the packets will go through Wireless\_Node\_1 > Wireless\_Node\_2, Wireless\_Node\_3, SDN\_Controller to Wireless\_Node\_5.

To configure the static routes on SDN\_Controller for all the nodes.

- a. Run the simulation again.

- b. Right-click **SDN\_Controller** and select NetSim Console.

Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe.

NetSim CLI console opens.

- c. Type the following commands on the NetSim CLI console, in the *<DeviceName with Device\_ID>* **route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #>** format.

**Wireless\_Node\_1 route add 11.1.1.5 mask 255.255.0.0 11.1.1.2 metric 1 if 1**

**Wireless\_Node\_2 route add 11.1.1.5 mask 255.255.0.0 11.1.1.3 metric 1 if 1**

**Wireless\_Node\_3 route add 11.1.1.5 mask 255.255.0.0 11.1.1.4 metric 1 if 1**

**SDN\_Controller route add 11.1.1.5 mask 255.255.0.0 11.1.1.5 metric 1 if 1**

12. Interpret the results.

- a. Click **View Animation** and see the Packet Animation. The packets reach Wireless\_Node\_5 via Wireless\_Node\_1 > Wireless\_Node\_2 > Wireless\_Node\_3 > **SDN\_Controller** > Wireless\_Node\_5.

- b. In the simulation results window select the **Open Packet trace** option in the left area. Once the packet trace opens apply filter in the **CONTROL\_PACKET\_TYPE/APP\_NAME** column to show only **OPENFLOW\_COMMAND** and **OPENFLOW\_RESPONSE** messages.

You will see that OpenFlow packets flow from Wireless\_Node\_1 > Wireless\_Node\_2 > Wireless\_Node\_3 > SDN Controller to Wireless\_Node\_5 as part of the commands executed for static route configuration.

### 3.5 Example 5: Configuring Static Routes for a WSN Network by using SDN

In this example static routes are configured in sensors using SDN commands executed in a SDN controller.

The WSN network model in this example consists of the following configuration:

- A subnet with 5 wireless sensor, 1 ad-hoc link, 1 wireless sink node, and a unicast sensor application running on one of the wireless sensors.
- One wireless Sensor is configured as the SDN controller.
- A unicast application from Wireless\_Sensor\_1 to Wireless\_Sensor\_5.
- Simulation time of 500 seconds.
- Packet trace is enabled.

To simulate the example for WSN using SDN:

Open NetSim and Select **Examples > Software Defined Networks > WSN StaticRoute** then click on the tile in the middle panel to load the example as shown in below screenshot

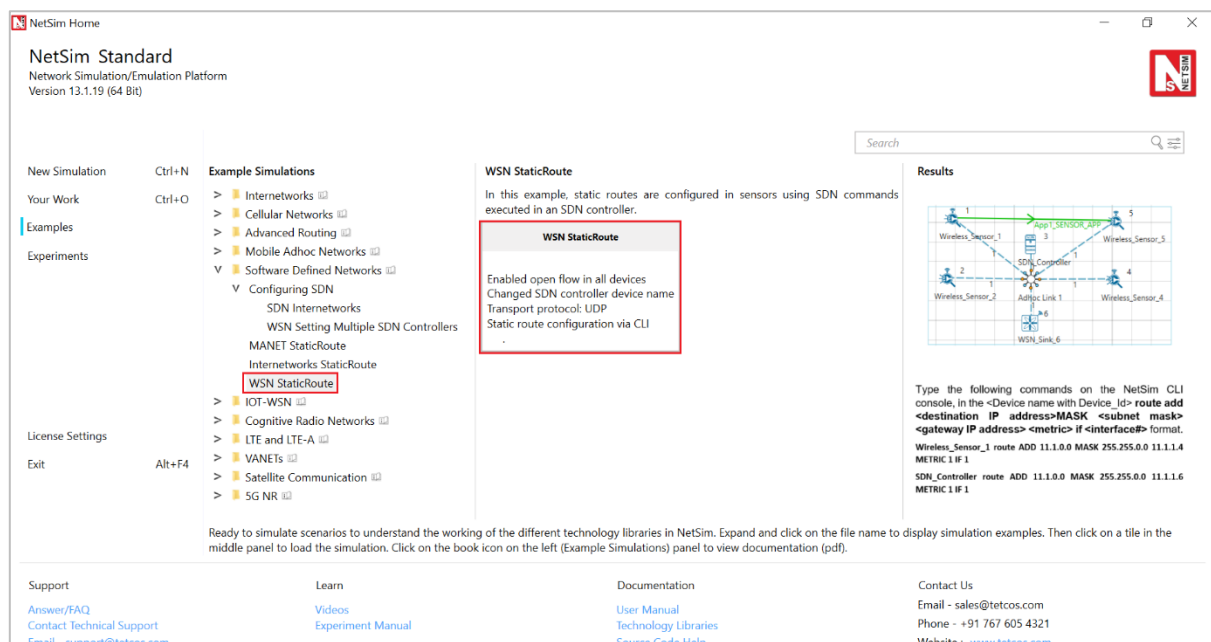


Figure 3-22: List of scenarios for the example of WSN StaticRoute  
 The following network diagram illustrates the network setup considered in this example:



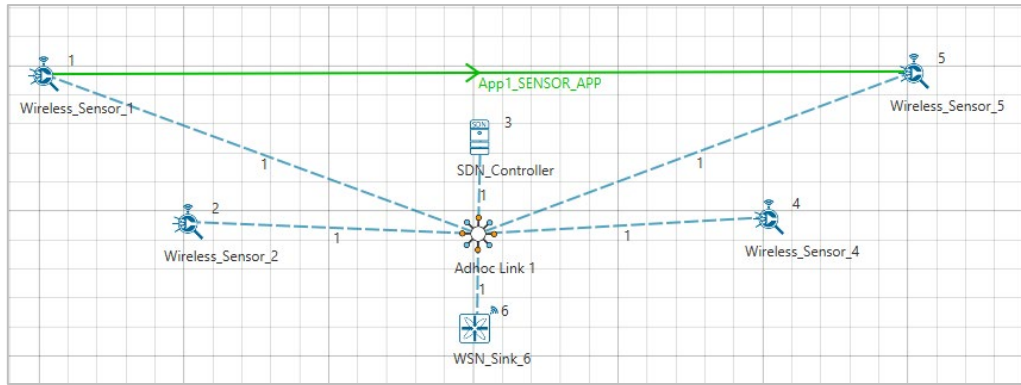


Figure 3-23: Network set up for studying the WSN StaticRoute

1. The following settings are done in the application layer properties of the devices for configuring SDN:

Device Name	Open_Flow	SDN_Controller	SDN_Controller_DeviceName
Wireless_Sensor_1	Enable	FALSE	SDN_Controller
Wireless_Sensor_2	Enable	FALSE	SDN_Controller
SDN_Controller	Enable	TRUE	NA
Wireless_Sensor_4	Enable	FALSE	SDN_Controller
Wireless_Sensor_5	Enable	FALSE	SDN_Controller
WSN_Sink_6	Enable	FALSE	SDN_Controller

Table 3-4: Set the properties for all the devices

2. Click on the Application icon present in the top ribbon/toolbar.
  - a. Sensor Application from Wireless\_Sensor\_1 to Wireless\_Sensor\_5 with default Generation Rate (Packet Size: 50Bytes, Inter Arrival Time: 1000000μs).
  - b. Set Transport Protocol to UDP.
3. In NetSim GUI Plots and Packet Trace are enabled.
4. Simulate the example. To do so:
  - a. Click on the Run button. The Run Simulation pop-up window appears.
  - b. Simulation time is set to 500 seconds.
  - c. In the Run time Interaction tab, the Interactive Simulation option is set to True.
  - d. Click **Accept**.
  - e. Click **OK**.

Simulation (NetSimCore.exe) starts to run. NetSimCore.exe displays the following message: waiting for first client to connect.

5. To use the SDN CLI Console:
  - a. Right-click **SDN\_Controller** and click NetSim Console. Now, the client (NetSimCLI.exe) starts and attempts to establish a connection with NetSimCore.exe.
6. Interpret the results.



- a. Click View Animation and see the Packet Animation.

The packets reach Wireless\_Sensor\_5 from Wireless\_Sensor\_1 > SDN\_Controller > Wireless\_Sensor\_5.

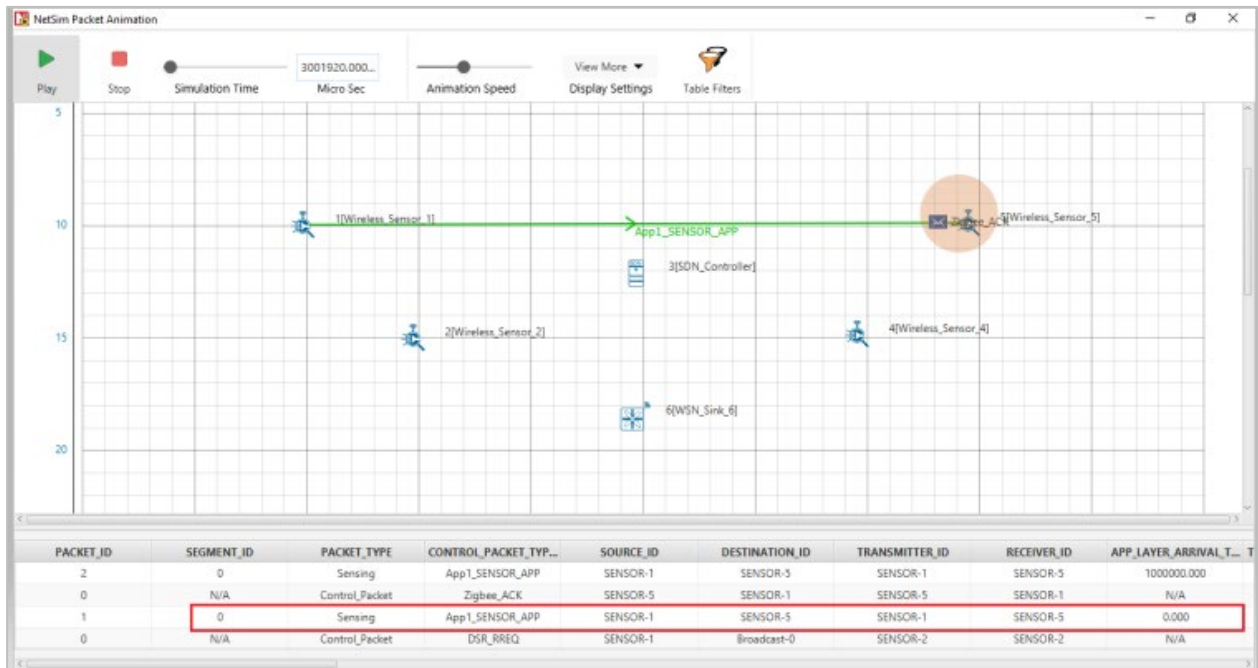


Figure 3-24: Direct communication between node 1 and node 5 in packet Animation window

7. Configure static routes such that the packets will go through Wireless\_Sensor\_1 to Wireless\_Sensor\_5 via SDN\_Controller.

To configure the static routes on SDN\_Controller for Wireless\_Sensor\_1

- a. Run simulation again.
- b. Right-click SDN\_Controller and click NetSim Console.

Now, the client (NetSimCLI.exe) starts and tries to establish a connection with NetSimCore.exe.

NetSim CLI console opens.

- c. Type the following commands on the NetSim CLI console, in the <DeviceName with Device\_ID> **route add <destination IP address> MASK <subnet mask> <gateway IP address> <metric> if <interface #>** format.

**Wireless\_Sensor\_1 route ADD 11.1.0.0 MASK 255.255.0.0 11.1.1.4 METRIC 1 IF 1**

**SDN\_Controller route ADD 11.1.0.0 MASK 255.255.0.0 11.1.1.6 METRIC 1 IF 1**

8. Interpret the results.

- a. Click **View Animation** and see the Packet Animation.

The packets reach Wireless\_Sensor\_5 from Wireless\_Sensor\_4 > SDN\_Controller to Wireless\_Sensor\_5.

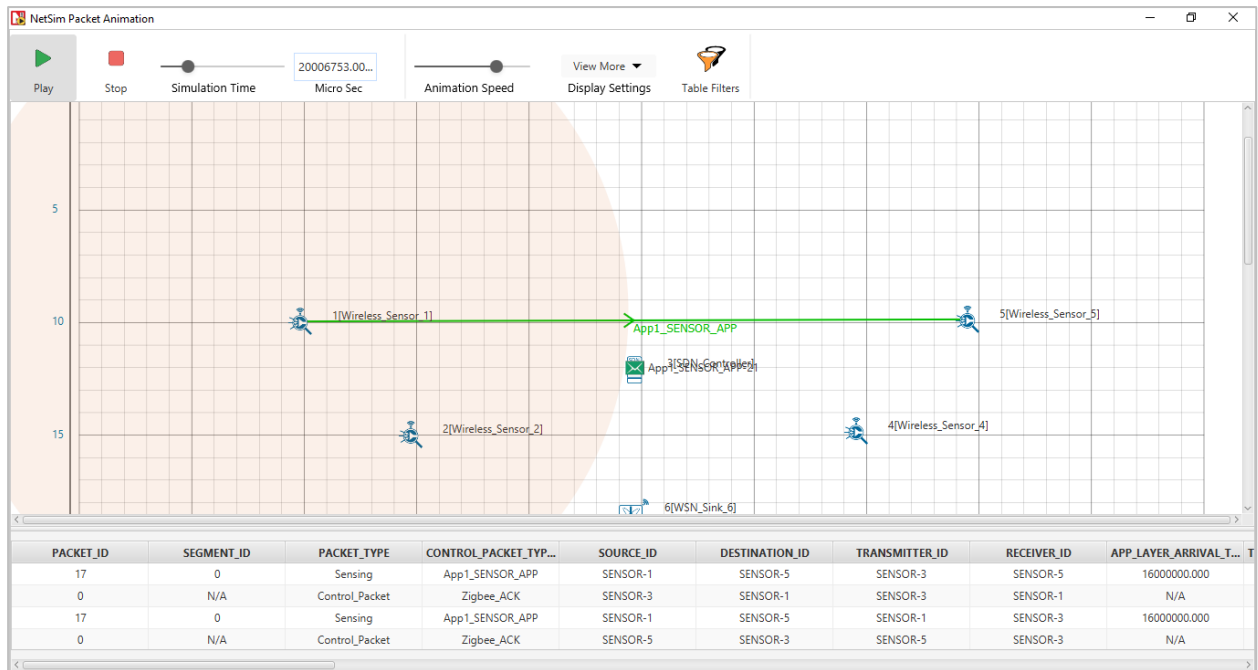


Figure 3-25: Communication between node 1 > SDN Controller > node 5 in packet Animation window

- b. In the simulation results window select the **Open Packet trace** option in the left area. Once the packet trace opens apply filter in the **CONTROL\_PACKET\_TYPE/APP\_NAME** column to show only **OPENFLOW\_COMMAND** and **OPENFLOW\_RESPONSE** messages. You will see that OpenFlow packets flow from Wireless\_Sensor\_4 to SDN\_Controller as part of the static route configuration done via console.

## 4 Latest FAQs

You can refer to the up-to-date FAQs about NetSim's SDN library at

<https://tetcos.freshdesk.com/support/solutions/folders/14000122307>.